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NON-INGESTED DOSE ASSOCIATED WITH PARTICULATE INGRESS INTO A PROTOTYPE SHELTER VIA THE VENTILATION SYSTEM

by
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ABSTRACT

Particulate penetration into the USNRDL experimental shelter via the ventilation system operating without filters was determined as a function of particle size. Relatively good agreement was found with the small amount of applicable Shot Small Boy data. Estimates of the dose within a shelter due to particulate penetration and deposit (ingress dose) were made using values of fallout model parameters for weapon yields of 100 to 100,000 KT (assuming 100 % fission). Ingress doses are presented as a function of particle size and downwind distance so that the particle sizes of importance may be determined for any given acceptable ingress dose.

SUMMARY

Problem

Fallout carried into a shelter via the shelter ventilation system becomes one of several sources of shelter radiation dose. Estimates of these doses are required to assess the hazard and thus determine requirements for ventilation countermeasures. Countermeasure specifications must then be developed to meet these requirements.

Particle transport into a shelter via a ventilation system is a function of particle physical characteristics: size, specific gravity, and shape; and ventilation system characteristics: air volume rate, air velocities, and air path. The resulting dose is a function of: time of exposure, amount and disposition of the particles in the shelter, and fallout radiological characteristics such as specific activity and decay.

The specific problems of concern in this report were (1) the determination of particulate penetration into the USNRDL experimental 100-man shelter via the ventilation system as a function of particle size, and (2) the estimation of ingress doses as a function of particle size to serve as a basis for determining particle sizes of significance to the ingress problem.

Findings

A relation between mass per unit area deposited outside and mass penetrating the shelter ventilation intakes was determined experimentally as a function of particle size, using several narrow size ranges of either glass beads or sand.

Particle penetration by the largest size range (500 to 700 μ) appeared to be due principally to bounce-in rather than entrainment by the air stream. Otherwise, penetration of intakes is an inverse function of particle size and a straight line was the best fit to a log-log plot of the data. Relatively good agreement was found with the small amount of applicable Shot Small Boy data.

Ingress dose was estimated as a function of mid-range particle size (if d_1 and d_2 = largest ans smallest particle size respectively, then $d_1 + d_2/2$ = mid range particle size) and as a function of downwind distance for weapon yields of 100 KT to 100,000 KT (100 % fission yield), using the experimental data and a simplified mathematical fallout model. A "worst case" was used for penetration to cover uncertainties in the data and assumptions necessary in the estimating technique. For this purpose it was assumed that all of the fallout penetrating the ventilation intakes was deposited in the shelter living area, though there is evidence that as little as 50 percent may reach the living area, the remainder being deposited on the steps and landing of the entrance. The maximum estimated ingress dose was 11.8 r at 167 miles downwind from a 100,000-KT detonation.

An acceptable ingress dose, or the lower limit of significant ingress dose, can be used to determine the particle sizes of importance. An example is given in discussing the curves presented.

Dose estimates are limited to the shelter and ventilation system design for which data were obtained; and also to fallout model conditions for single-weapon detonations and 15-mph winds at all altitudes. If dose estimates are needed for other ventilation or fallout conditions, this report may be useful as a basis for planning and improving experimental and estimating techniques.

CONTENTS

FIGURES (Cont'd)

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Shelter ingress studies were first conducted at Operation PLUMBBOB, 1958.[1] A buried shelter was ventilated at a rate of 600 cfm drawing air from a low-velocity tunnel through two mushroom type intakes at the sides of the shelter door. The entrance to the tunnel, facing away from ground zero, was a 30-ft long underground passageway and was entered from ground level via an open ramp. Air velocity at the tunnel entrance was approximately 30 ft/min. Fallout standard intensities (intensity due to total deposited fallout corrected for decay to r/hr at 1 hr) of 19 and 36 r/hr were obtained above the shelter, following Shots Diablo and Shasta, respectively, both 500-ft tower shots. For the two shots, respectively, particles as large as 120 and 80 μ reached the shelter in detectable quantities and most were less than 20 or 15 μ. It was estimated that no inhalation hazard would have existed in the shelter and that no filter would have been necessary and that external* dose due to ingress activity would have been on the order of the dose due to gamma penetration from fallout deposited over the shelter. However, it was concluded that the results were not general enough to extrapolate to other fallout conditions.

In the summer of 1961 a prototype 100-man underground shelter at Camp Parks, California was used for ventilation ingress tests. A series of tests using radioactive simulants was run, designed to determine particulate ingress into the shelter via the ventilation system as a function of particle size. At the conclusion of this test series a proposal was made to determine penetration of typical shelter ventilation air intakes as a function of particle size, fallout mass, intake face velocity, flow rate, and wind speed. The purpose of this extended scope was to provide design specifications for ventilation intake fittings and performance specifications for ventilation filters that might be considered necessary or desirable.

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*External dose refers to dose due to radiation sources external to the body. Dose due to radiation sources within the body as the result of ingestion or inhalation is called internal dose.

A second test series using non-radioactive simulants was run on the shelter, during January 1962, to test the uniformity of simulant dispersion above the ventilation air intakes.

Shot Small Boy ventilation ingress tests[2] were designed to determine particulate penetration of air intakes as a function of particle size and intake face velocity. At each of six downwind locations a flow rate of 43 cfm suitable for a family type shelter, was maintained through each of five intakes. These intakes were 3-inch vertical pipes, four of which were covered with mushroom-type hoods sized to give face velocities of approximately 22, 44, 88, and 440 ft/min. The fifth was uncovered, and was essentially a combined high-volume air sampler and small-area fallout collector, with a face velocity of approximately 1000 ft/min. The principal results obtained were that the activity collected by the hooded intakes at three downwind locations was 25 % or less of the activity collected by the open intake at the same location. Fifty percent or more of each hooded intake sample activity was associated with particles smaller than 44 μ in size and negligible amounts were associated with particles larger than 150 μ. Now, the undertaking of the investigation reported herein.

1.2 OBJECTIVES

Main purpose of the work, toward which the objectives lead:

(a) To determine particulate penetration into and distribution in the USNRDL experimental shelter due to operation of the ventilation system without filters, as a function of particle size.

(b) To estimate the dose in the shelter living area due to particulate deposition, as a function of particle size.

1.3 APPROACH

Deposition of several narrow size ranges of particles within the shelter and outside the shelter in the vicinity of the air intake fittings was determined experimentally for a zero wind condition. From these data a relation of total penetration to mass deposited per unit area outside was determined for each particle size range. A curve was drawn for these penetration factors as a function of particle size and compared to several curves derived from comparable data obtained at Shot Small Boy.

Ingress doses were calculated using penetration factors for a "worst case" (assuming that all of the fallout penetrating the ventilation intakes was deposited in the shelter living area, though there is evidence that as little as 50 percent may reach the living area, the remainder being deposited on the steps and landing of the entrance) and a fallout model which relates the parameters of the mid-range of particle-sizes arriving at a downwind location both to the standard intensity and to the half-range of particle sizes, for various weapon yields. If d_1 = the largest particle size and d_2 = the smallest particle size at a given location then $d_1 - d_2$ = the range, $d_1 + d_2/2$ = the mid-range and $d_1 - d_2/2$ = the half range. Fallout parameter values are for the downwind region of maximum radiation intensity (hot line) due to a 15-mph wind at all altitudes. Only those weapon yields were considered which would produce hot-line doses of 50 r or greater.

To provide a means of determining particle sizes of importance to the shelter ventilation ingress problem, the ingress dose estimates are presented graphically as a function of mid-range particle size. For any given lower limit of significant ingress dose, the corresponding mid-range particle sizes can be determined from these curves. Fallout model mid-range particle sizes are presented as a function of particle size half-range so that, for the mid-range particle sizes determined as described above, the full range of particle sizes of significance to the ingress problem can be determined.

Estimated ingress doses are also presented as a function of downwind distance to determine the region of interest for the assumed lower limit of significant ingress dose. Outside doses are presented as a function of downwind distance for use with known or assumed shielding factors in calculating the dose in the shelter due to gamma penetration from outside. This latter dose plus the ingress dose gives the total shelter dose which may be compared to an acceptable shelter dose. Or, for an acceptable shelter dose and known shielding factor, the acceptable ingress dose can be determined and compared to the estimated ingress dose.

The data presented and the ingress dose estimates with their limitations and assumptions are intended to provide a basis for evaluation of future needs in the shelter ventilation program.

CHAPTER 2

PROCEDURES

The general plan of this experiment was to disperse fallout in several narrow size ranges from the top of a tower enclosing the shelter entrance with the ventilation system operating. A mass deposit level of 200 g/ft^2 was decided upon as a level that would exceed any that might be encountered beyond the region of throwout and stem fallout from a land surface detonation of a multimegaton weapon. Since wind would affect the air flow characteristics around the inlet ventilators, a zero wind velocity was used. Each particle size range was run under three test conditions:

(a) Filters at inlet ventilators to determine material that could pass the mushroom-headed covers.
(b) Filters in their normal location to determine material that would enter the shelter living area if filters were not present.
(c) Filters over the exhaust ventilator to determine material that would pass through the shelter without being deposited.

Deposit samples were taken in representative areas upstream from the filters to determine the amount of material that would deposit in those locations. Preliminary tests to determine the uniformity of dispersion were made using non-active particles. Particles tagged with radiolanthanum 140 were used during the tests to measure ingress into the shelter because this was the only way in which the amount of material collected on the filters could be determined.

2.1 DESCRIPTION OF SHELTER

The USNRDL expeimental shelter[3] is a buried flexible-steel-arch structure, 25 ft wide by 48 ft long, similar to that used by the Navy as an ammunition storage magazine.* The base of the shelter is 12 ft

*References 8 and 9 are subsequent reports on development of this shelter.

below ground level, and 3 ft of earth fill is added over the top roof line to provide a minimum of 3 ft of earth shielding. Each of 100 shelterees is provided with 12 ft^2 of area and 117 ft^3 of gross volume. The shelter is equipped to maintain life and basic health for approximately 14 days. The entranceway has a 90° bend to prevent any direct radiation from entering the shelter. Fresh air is pulled into the shelter by an electrically driven blower at a rate of 1500 cfm. Figure 2.1 shows the path followed by the ventilation air into the entranceway, through the shelter living area, and out the exhaust ventilator.

The ventilation system is designed to minimize the entry of fallout particles. Intake mushroom covers can be closed when necessary to provide a blast-tight seal. The gross volume of the shelter is such that the 100 shelterees can exist on the air contained inside the shelter for 3-1/2 hours.

Power for operating the blower is from public utility lines; however provision to operate from a gasoline-driven generator is available. Since combustion and cooling air required for the operation of this generator is drawn in through the same inlet ventilators which provide fresh air for the shelter, the inlet face velocities and entranceway air velocity will be approximately doubled when this generator is operating. All the tests reported here were made without the generator running. The face velocity across the inlet ventilators was 750 ft/min and the velocity down the entranceway was approximately 30 ft/min.

Two 24-inch by 24-inch MSA Ultra-Aire Particulate Filters, mounted in normal use just ahead of the blower at the base of the stairs, filtered all the air before discharging it through a single diffusor over the door into the living area (see section 2.4 for other test locations of filters). The air is mixed in the shelter by natural convection forces and discharged from the shelter via the 2-ft-diameter exhaust vent in the roof of the shelter at the opposite end from the entrance.

2.2 SIMULANT PREPARATION

The fallout simulant used in these tests was prepared by the same processes used to prepare simulant for the Target Complex[4] tests. Glass beads with a specific gravity of 2.6 (approximately that of sandy fallout) were used as the particulate because of their ideal spherical shape and their availability in the 18 to 40-μ size range.

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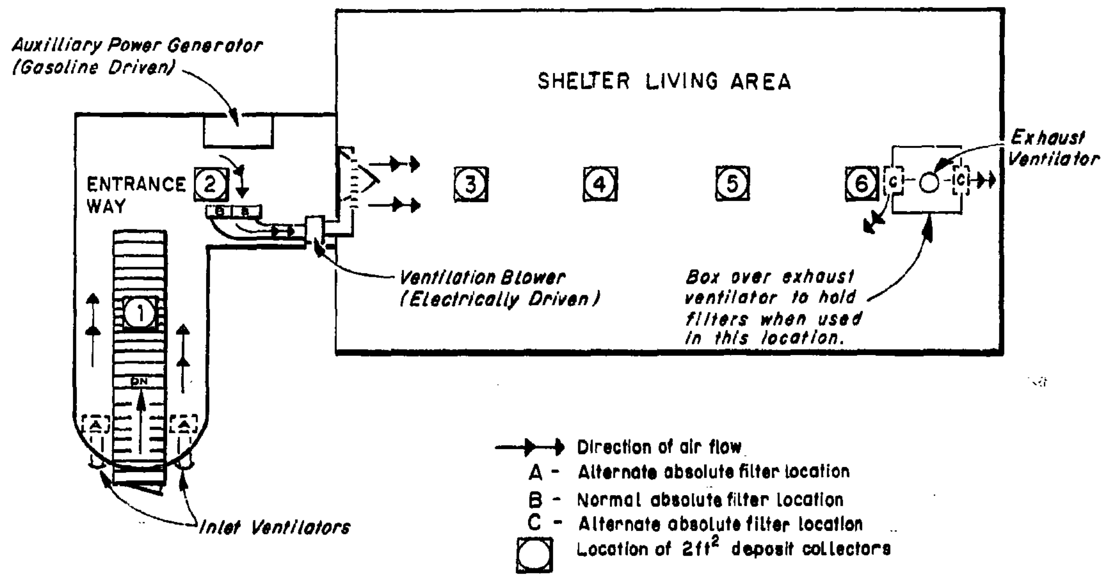

Fig. 2.1 Schematic Plan of Prototype Shelter: Ventilation System and Aerosol Ingress Sample Collectors

Particles of the desired size range were put into a small (1-1/2 ft^3) cement mixer. A solution containing the desired amount of radiolanthanum-140 was atomized on the particles with continuous mixing. When all the tracer had been added, the mixture was dried by applying hot air to the outside of the rotating drum. No sodium silicate was added to affix the tracer to the particles as had been done to the Target Complex simulant, as no water was used during particle recovery and no possibility of leaching was foreseen.

When the contents of the mixer were dry, they were transferred to a shielded container and transported to the shelter site.

2.3 SIMULANT DISPERSION

The simulant was poured into a hopper on top of the tower over the shelter entrance and dispersed as described in 2.6.1. The total amount of material dispersed in each test run was selected on the basis of a planned deposit of 200 gm/ft^2, assuming all the material deposited uniformly over the tower base area. This value was adopted from previous tests on Roof Washdown[5] and was dispersed at a rate of 100 $g/ft^2/hr$.

2.4 SAMPLES

Interior deposit samples were collected as described in 2.6.3. A total of 6 samples for each test: four samples on 10-ft centers down the centerline of the shelter proper in the line of air movement from supply to exhaust, one sample at the base of the stairway, and one sample half-way down the stairs.

The weight dispersed (deposited or available for intake) per unit area represents the mass level of the simulated fallout field. Dispersion was not uniform over the area at the base of the tower and mass distribution varied for each particle size range used. Therefore it was necessary to determine the weight dispersed in the vicinity of the intakes to represent the fallout field mass level. For this purpose, samples were taken in a grid above, but not over, the intakes on some test runs. Examination of the data indicated the need for additional tests which were run subsequently with non-radioactive glass spheres. Inlet covers were removed and samples were caught in plastic bags taped to the inside of the inlet pipes. In addition, sample pans lined with plastic sheets to minimize losses due to bounce, supported in a grid above the entrance, were used as in the previous test runs. Similar tests were run with the inlet covers in place to determine the amount of particles that would bounce in.

The two shelter filters described in 2.6.2 were used to collect aerosols and were mounted in one of three different locations depending on the conditions of the test. When they were mounted inside the air intakes they measured the total amount of material that entered the entranceway. When they were mounted in their normal location at the base of the stairs they measured the material that had not deposited in the entranceway and was available to enter the shelter proper. When they were mounted over the air exhaust vent they measured the material that failed to deposit in the shelter and was carried out in the air stream.

2.5 METHODS OF SAMPLE ANALYSIS

Samples of the radioactive simulant used in each test were counted to determine the specific activity, using the equipment described in 2.6.4. Each sample collected during the test was counted, and using the specific activity, the total mass collected was calculated.

A known amount of activity was evenly distributed in a clean filter and the whole unit was counted. The counts per unit activity obtained with this "standard filter" was used as a calibration factor to calculate the total activity collected on the test filters. From this, the total mass collected on a filter could be calculated when the specific activity was known.

2.6 EXPERIMENTAL EQUIPMENT

2.6.1 Particle Disperser

The equipment used to disperse the particles over the shelter entrance was basically the same as that used in the Roof Washdown Studies.[5] A 24-ft tower with a base area of 64 ft^2 was erected over the entrance to the shelter, as shown in Fig. 2.2, to permit dispersion of the particles at zero wind velocity. In addition, the tower height was such that the dispersed particles reached their terminal settling velocity.

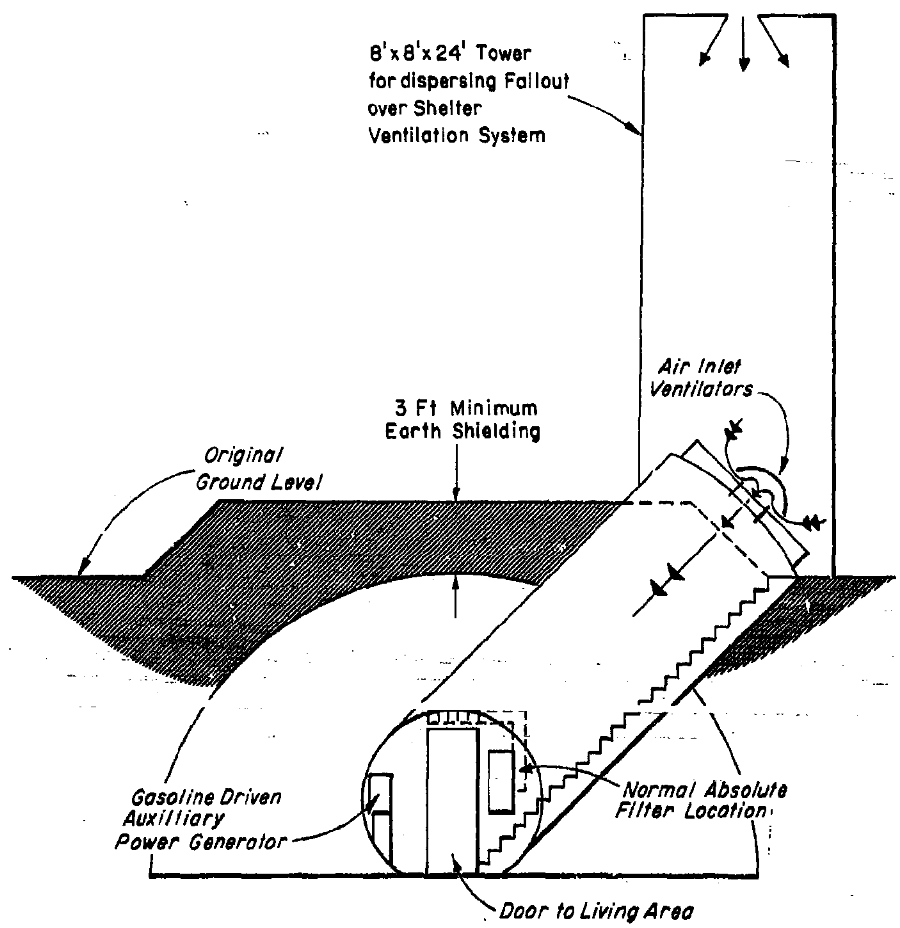

Fig. 2.2 Schematic Plan of Tower for Particle Dispersion

A hopper equipped with a Syntron Vibrator fed the particles at a fixed rate to a standard sand-blasting nozzle which was mounted inside the top of the tower. The particles discharged vertically upward from the nozzle against a 4-in. square rubber plate which deflected the particles downward, forming a cloud of particles which fell over the shelter entrance.

2.6.2 Filters

The filters used in this experiment were the same as those installed in the original shelter. Two 24-in.^{2} MSA Ultra-Aire Absolute Particulate Filters were used for each test. These filters had an efficiency of 99.97 % for 0.3-μ particles of DOP (dioctyl phthalate).

2.6.3 Deposit Collectors

The deposit collectors were merely sheets of Saran with a total area of 2 ft^2 (288 in.^{2}) per sheet. The collectors were sprayed with oil to form a thin film which prevented loss of particles during handling.

2.6.4 Counting Equipment

The shelter filters were counted in a low-geometry scintillation counter which employs a 1-in. long x 1-in. diameter NaI crystal scintillation detector. The detector was mounted in the top of a 2-in. thick lead shielded cave with the center of the detector approximately 28 in. above the center of the shelf used. The cave was lined with wood of inside dimensions of about 27 x 28 x 38 in. A Nuclear Chicago Model 183 B scaler was coupled to the detector unit.

The deposit samples were counted in either a 4 π ionization chamber or a deep well scintillation counter, depending on the activity level. Samples were counted on both counters to obtain a correlation between counters whenever possible. Saran samplers were rolled and folded into a 1-in. diameter x 1-in. long package to fit into the counters and prevent sample handling losses.

The 4 π ionization chamber was an argon filled (600 psig at 70°F) steel chamber 11 in. in diameter x 14 in. high. It was shielded with 3 in. of lead and has a re-entrant sample thimble 1-3/4 in. x I.D. x 12 in. deep. Current produced in the chamber by ionizing radiation was applied to suitable load resistors. The resultant voltage drop drove a plate difference amplifier and was read out on a microammeter.

The deep well crystal counter is a 3-in. NaI crystal with a recess for a 100-ml lusteroid test tube, was lead shielded, and was operated with a Nuclear Chicago Model 182 power supply and a Berkeley Digital Scanner, Model 15565.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 TEST RESULTS

The total amount of material deposited in each shelter component was estimated from one sample on the stairs, one on the landing, and four in the shelter living area. In the latter, the four samples were uniform for each test run.

The estimated deposits and filter collections are presented in Table 3.1 by particle size ranges. A mass median diameter is given for each particle size range based on sieve analyses presented in Figs. 3.1 and 3.2. The weight dispersed per unit area in the vicinity of the intakes was not measured on all test runs. Where given as a plain figure, the weight was derived from a sample taken on that run; where given in parentheses the weight is from a sample taken on a similar run. Where weights and a range ($\pm$) are given, they are the average of samples from four test runs made to test the uniformity of dispersion at the base of the dispersing tower for each particle size group. These weights were used where no similar data was available.

The last two columns give the total penetration, which is the sum of estimated deposits and filter collections, and a penetration factor which is the ratio of the total weight penetrating the intakes to the specific weight (g/ft^2) deposited outside. Implicit in this factor is the assumption that penetration is directly proportional to the specific weight of material deposited in the vicinity of the intakes for a given particle size range.

Note that penetration decreases as particle size increases up to a mass median diameter of 300 μ. Inside deposits were very heavy for the smallest particle size (18-40 μ), giving the appearance of a uniform snow cover, while for the larger particle sizes no deposit was visible. However, it appears that particle bounce-in increases with particle size. It is not a factor below about 350 μ but might be the principal factor causing penetration of particles in the 500-700 μ range and

TABLE 3.1

Summary of Aerosol Ingress Tests on NRDL Prototype Shelter

Run No.	Particle Size: Nominal Range (μ)	Particle Size: Mass Median Diameter (μ)	Dispersed (g/ft^2)	At Inlet Filter (g)	Weight: On Stairs (g)**	Weight: On Landing (g)**	Weight: At Shelter (g)	Weight: In Shelter (g)***	Weight: At Exhaust (g)	Weight: Total Penetration (g)	Penetration Factor: (g) penetration / (g/ft^2) outside deposit
15	18- 40^B	27	100 ± 10	1250	-	-	-	-	-	1250	12.5
16	18- 40^B	27	100 ± 10	-	337.9	519.9	-	873.5	59.0	1790	17.9
12	62- 88^B	65	290 ± 55	440	-	-	-	-	-	440	1.52
11	125-177^B	163	206 ± 14	60	-	-	-	-	-	60	0.291
14	125-177^B	163	206 ± 14	-	23.0	115	-	33.9	8.2	76.6	0.372
X	125-177^B	163	206 ± 14	0.0	-	-	-	-	-	0.0	-
1	177-390^S	285	133*	-	1.86	0.41	2.61	-	-	4.88	0.0363
2	177-390^S	295	155*	-	2.63	0.54	-	2.15	0.92	6.24	0.0404
10	250-350^B	305	250 ± 25	19.6	-	-	-	-	-	19.6	0.0784
X	250-350^B	305	250 ± 25	0.0	-	-	-	-	-	0.0	-
3	350-600^S	415	105*	-	1.01	0.51	5.10	-	-	6.62	0.0630
4	350-600^S	415	82*	-	4.03	1.09	-	3.75	-	8.87	0.1082
5	350-600^S	415	(82)	-	0.60	0.27	2.79	-	-	3.66	0.0446
6	350-600^S	415	(82)	-	0.64	0.19	-	0.04	1.08	1.95	0.0238
7	500-700^B	583	41*	-	4.61	0.79	2.93	-	-	8.33	0.2032
8	500-700^B	583	(41)	-	0.62	0.35	-	0.03	0.15	1.15	0.0278
9	500-700^B	583	58 ± 10	6.5	-	-	-	-	-	6.5	0.1121
X	500-700^B	583	58 ± 10	5.3	-	-	-	-	-	5.3	0.0913

Run X - Bounce-in Tests (no airflow)

Weight Dispersed - Avg. and Range (±) of 4 runs to test uniformity of dispersion
*Sample taken during test run
( ) Value of sample from similar test run

** Stair and landing area: 30 ft^2 ea.
***Shelter floor area: 1200 ft^2

S = Sand particles
B = Glass beads

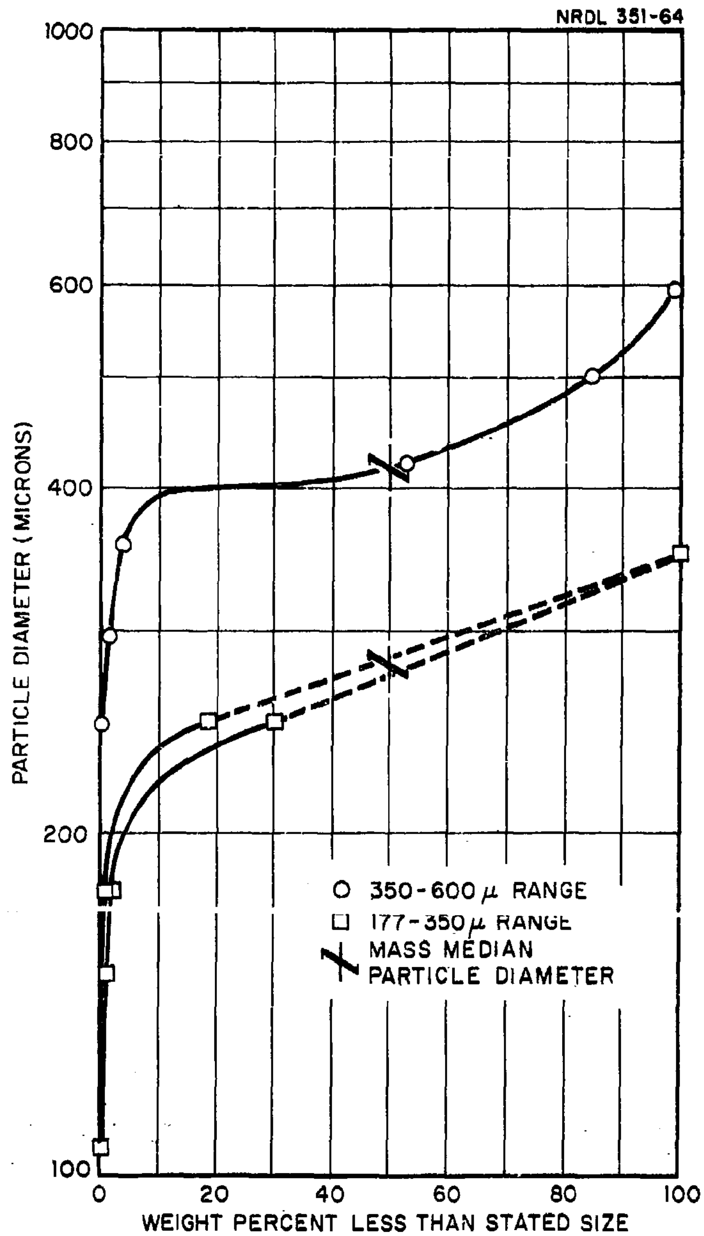

Fig. 3.1 Sieve Analyses of Sand

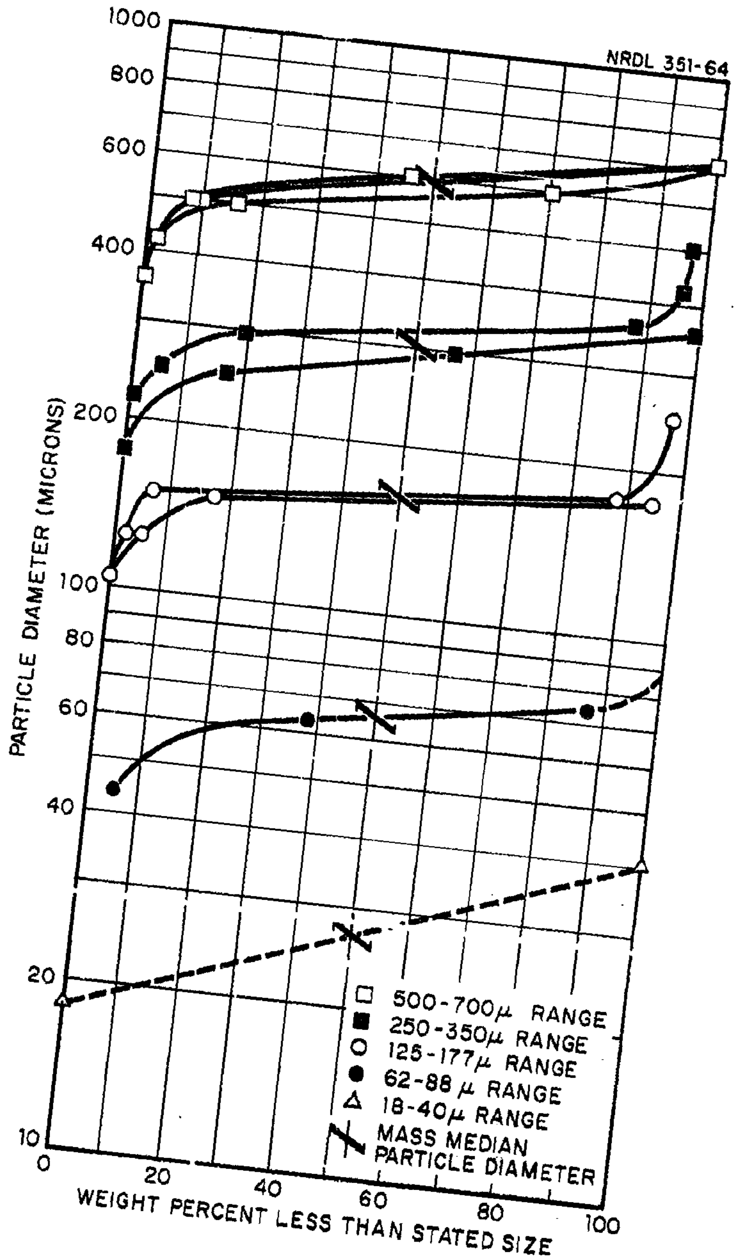

Fig. 3.2 Sieve Analyses of Glass Beads

assumedly for larger particles. Bounce-in is due to the particular geometry of the entrance cover and intake design.

The fraction of the total penetration that was found in the shelter living area or the shelter filter, assuming that the latter sample would have been transported into the shelter had no filter been in place, was on the order of 50 % of the total for particles less than 350 μ; and for the two test runs of the 500-700 μ range was 15 and 35 %. However, for the 350-600 μ range, 75 % of the total was found in the shelter filter on two test runs, and 42 % was deposited in the shelter on a third test run. A fourth test run shows almost no deposit in the shelter but 50 % of the total was found in the exhaust filter. This inconsistency and others are undoubtedly the result of inaccuracies inherent in low counting rates and the poor representation of an area by a single sample when deposits were very light.

3.2 PENETRATION AS A FUNCTION OF PARTICLE SIZE

The factor of penetration weight to outside unit area deposit weight was plotted on log-log paper as a function of particle size (using the mass median diameter of each particle size range) and a "best fit" line was drawn through the points as shown in Fig. 3.3. The curve shown apparently does not include the effect of bounce-in for the largest particle size but may be a reasonable approximation of penetration due to air movement of particles.

Total penetration has been presented so that it may be used for a comparison with Small Boy data and because it is intended for use in estimating dose due to penetration for a "worst case". The "worst case" as far as the shelter test data is concerned is based on the assumption that all of the material penetrating the intakes is deposited within the shelter living area rather than a fraction of the total (on the order of 50 %) as indicated by most of the data. This assumption should be adequate to provide estimates of dose which would not be exceeded by an increase in penetration due to wind interaction with the intake fittings (the shelter tests were conducted under a no wind condition) and due to the emergency generator being in use (see Chapter 2, Section 2.1). Whether the higher air flow due to generator operation, and hence penetration to the stairs and landing, might also result in higher living area penetration is a matter of conjecture. There certainly will be some increase in dose near the shelter door.

3.3 COMPARISON WITH SMALL BOY DATA

Some measurements of penetration of covered intakes were obtained at Shot Small Boy. Surface winds were 5 to 10 mph. The highest intake face velocity was 440 ft/min with a flow rate of 42.5 cfm, compared to 750 ft/min and 1500 cfm for the shelter tests. Penetration data for this intake at two locations can be compared to the Camp Parks data, assuming that penetration is directly proportional to flow rate, 1500 cfm and 42.5 cfm, and adjusting the Small Boy data accordingly. The effect of face velocity differences will be neglected as no proportionality factors are known. Penetration will certainly increase with an increase in face velocity, but the increase may vary with particle size. Small Boy data were inadequate to determine this effect.

With the above limitations, and the use of Small Boy activity data instead of weight data (weight data included some pre-shot inactive material collections), penetration factors for particle size groups and totals were calculated and are presented in Fig. 3.4 for Small Boy location 203 and Fig. 3.5 for Small Boy location 507. The ratios are for one intake sample compared with each of three pan collections. The shelter curve is shown as a dashed line. In spite of the various assumptions that went into the comparison of the Small Boy data with that of the shelter, it is seen that reasonable agreement is achieved.

The particle size groups were taken from cumulative percent sieve analyses of the samples, and the mid-range of each group was used to represent the group. Where data was available there was little difference between mass median diameter and the mid-range particle size for each group. The use of the mid-range size permits the use of a single size to represent both outside and penetration samples when a penetration factor is determined. However this could not be done when a factor is determined for the total samples, as the penetration and outside samples are very different in the upper limit of range (hence have widely different mid-range particle sizes) and have a lesser but appreciable difference in mass median particle sizes. Therefore the penetration factors for the total samples are represented by lines between the mass median diameters of the outside and penetration samples. Similarly each point for a penetration factor curve might be represented by a line if the shift in particle size distribution between outside and penetration sample of a group were taken into account. The smaller the range considered, the more closely would the line approach a point. The data are not available for such an approach and such a refinement does not seem necessary at this time. Note that in each case the curve lies between the limits of the vertical lines representing the penetration factors for the total samples.

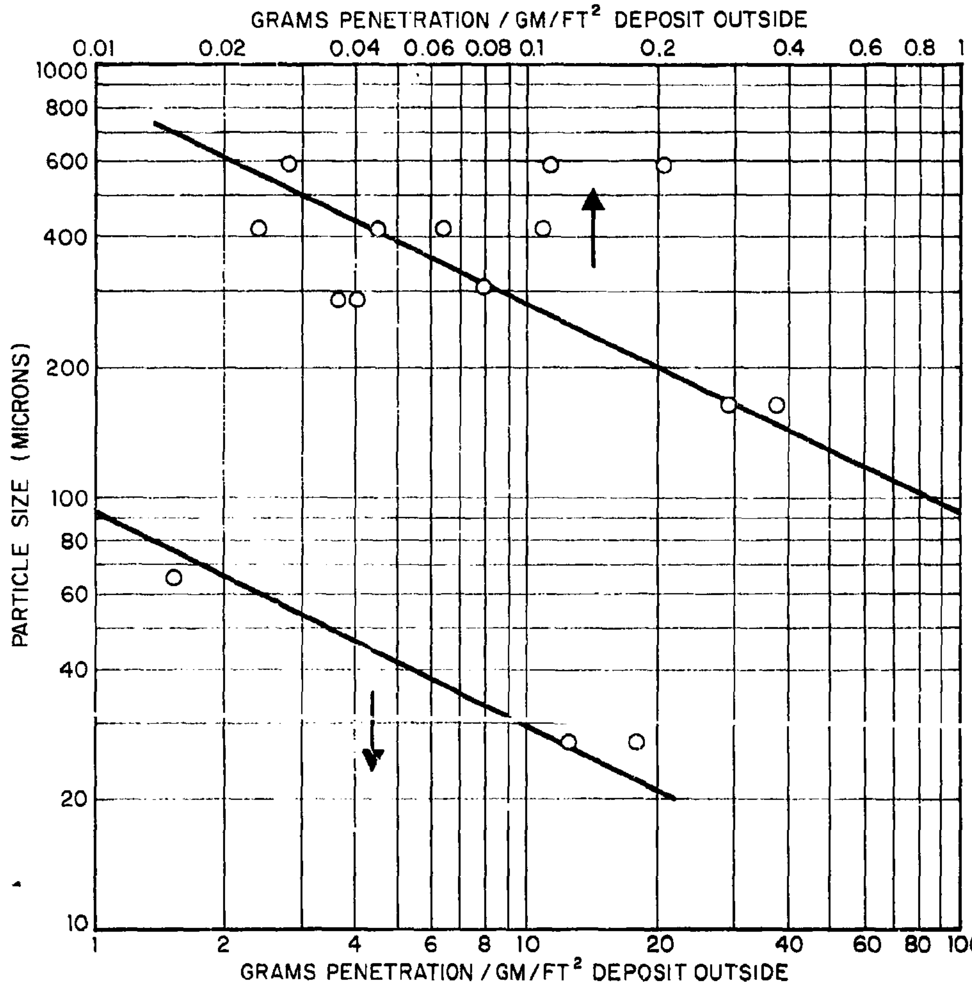

Fig. 3.3 Penetration Factor vs. Particle Size

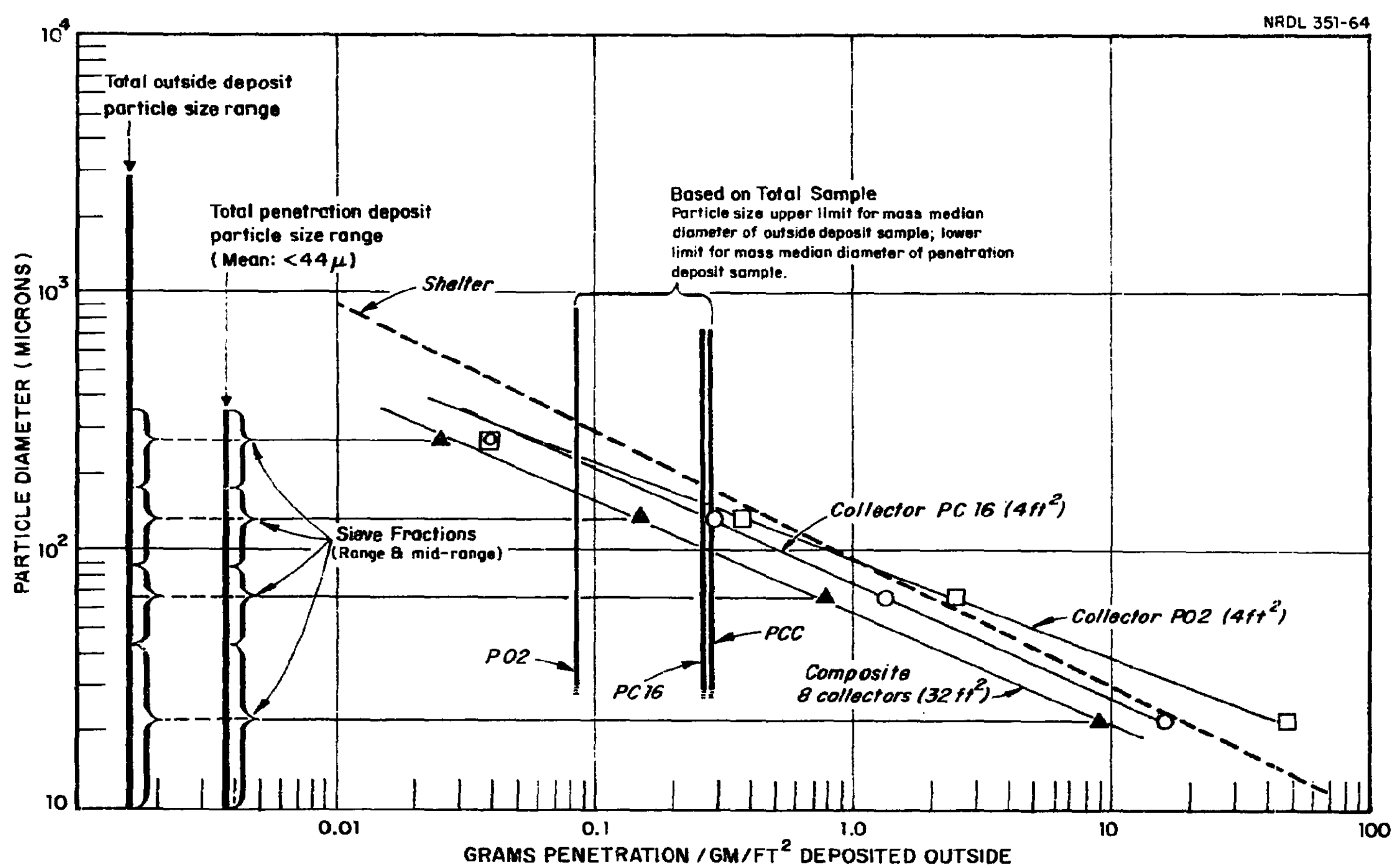

Fig. 3.4 Penetration Factor vs. Particle Size at Location 203 (Shot Small Boy) and for Shelter

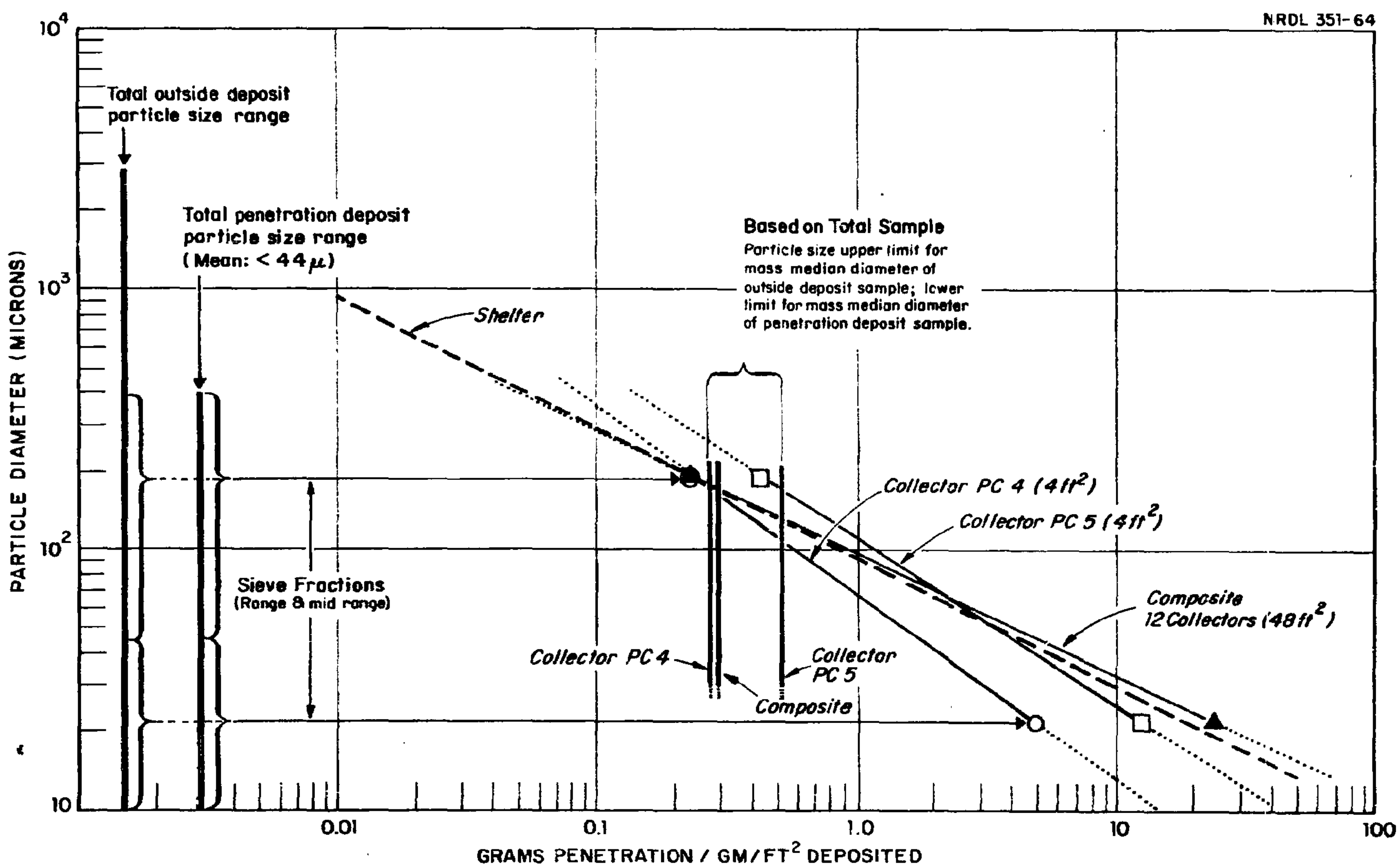

Fig. 3.5 Penetration Factor vs. Particle Size at Location 507 (Shot Small Boy) and for Shelter

The curves for the 507 location, Fig. 3.5, are based on only two particle size ranges. The upper limit for the penetration sample was arbitrarily selected as 350 μ because 98 % of the fallout collected was associated with particles less than 350 μ. It seems probable that 44 to 350 μ is too wide a range to provide a direct comparison with the shelter data and that, if this could be broken into several ranges, the 507 curves might more closely resemble the 203 curves.

3.4 ESTIMATION OF INGRESS DOSE

To assess the significance of fallout penetration into a shelter it is necessary to estimate the resulting dose. With the high efficiency filters properly installed, the dose will be due to radiation from filter collections and fallout in the entranceway. However, the question most often asked is whether filters are necessary and what particle sizes are most important. Therefore dose estimates as a function of particle size have been made from the penetration factors obtained in these tests, together with values of fallout model parameters from Reference 6. The details of the method of calculating doses is given in Appendix A. Fallout model parameters for a surface burst of various weapon yields from 1 KT* to 100,000 KT* are: standard intensity (intensity due to deposited fallout corrected for decay to r/hr at 1 hr) and downwind distance as a function of mid-range particle size; and mid-range particle size as a function of particle size half-range. A mean time of arrival at downwind locations was determined from the downwind distance and wind speed. It is assumed that the total penetration is deposited uniformly over the floor of the shelter living area instantaneously at the mean time of arrival.

The fallout region for which estimates have been made is downwind along the hot line, the region of maximum radiation intensity, from a single detonation of a 100 % fission weapon as predicted by Reference 6 for a 15-mph wind at all altitudes.

*Assuming 100 % fission.

3.5 INGRESS DOSE ESTIMATES

These estimates are presented as a function of mid-range particle size (a fallout model parameter) in Fig. 3.6 (see Appendix A for calculations) for weapon yields given in Reference 6. The points shown are ingress doses upon which the curves are based, but they also represent outside doses as indicated by the key. As a basis for determining particle sizes of importance, it will be assumed that 1 r is the lower limit of significant ingress dose. Note, however, that the total shelter dose is composed of the ingress dose, plus the dose due to gamma penetration from fallout deposited over the shelter and from cloud passage. For a lower limit of 1 r, it will be seen that mid-range particle sizes are from 42 to 380 μ and that the doses considered are due to fallout from weapons of yields greater than 2500 KT. The maximum estimated ingress dose is 11.8 r for which the mid-range particle size is 90 μ.

Mid-range particle size as a function of half-range is given in Fig. 3.7, reproduced from Fig. 2B of Reference 6, to provide a means of determining the total particle size range of interest. From the 100,000 KT-curve the half-range is 10 μ for a mid-range of 42 μ, or a total range of 32 to 52 μ. Similarly for a mid-range of 380 μ the total range is from 85 to 675 μ. Considering 1 r as the lower limit of significant ingress dose, the particle sizes of interest range from 32 to 675 μ. Note, however, that the total range of 85 to 675 μ for the mid-range of 380 μ is too great for the simplifications used in dose estimation due to differences in the times of arrival of the largest and smallest particles. Such large total ranges should be broken up into several increments and the dose estimated for each increment. The fallout model parameters do not include particle size distribution, and further assumptions necessary to refine these estimates do not appear to be warranted at this time. Some compensation for these inadequacies has been provided through the use of the total penetration factor, as mentioned previously.

It is also of interest to determine the region in which significant ingress doses may occur for the conditions on which these dose estimates are based. Ingress doses are presented as a function of downwind distance in Fig. 3.8. For doses of 1 r or greater the region of interest is from 45 to 540 miles downwind. The maximum ingress dose occurs at 167 miles for a weapon yield of 100,000 KT.

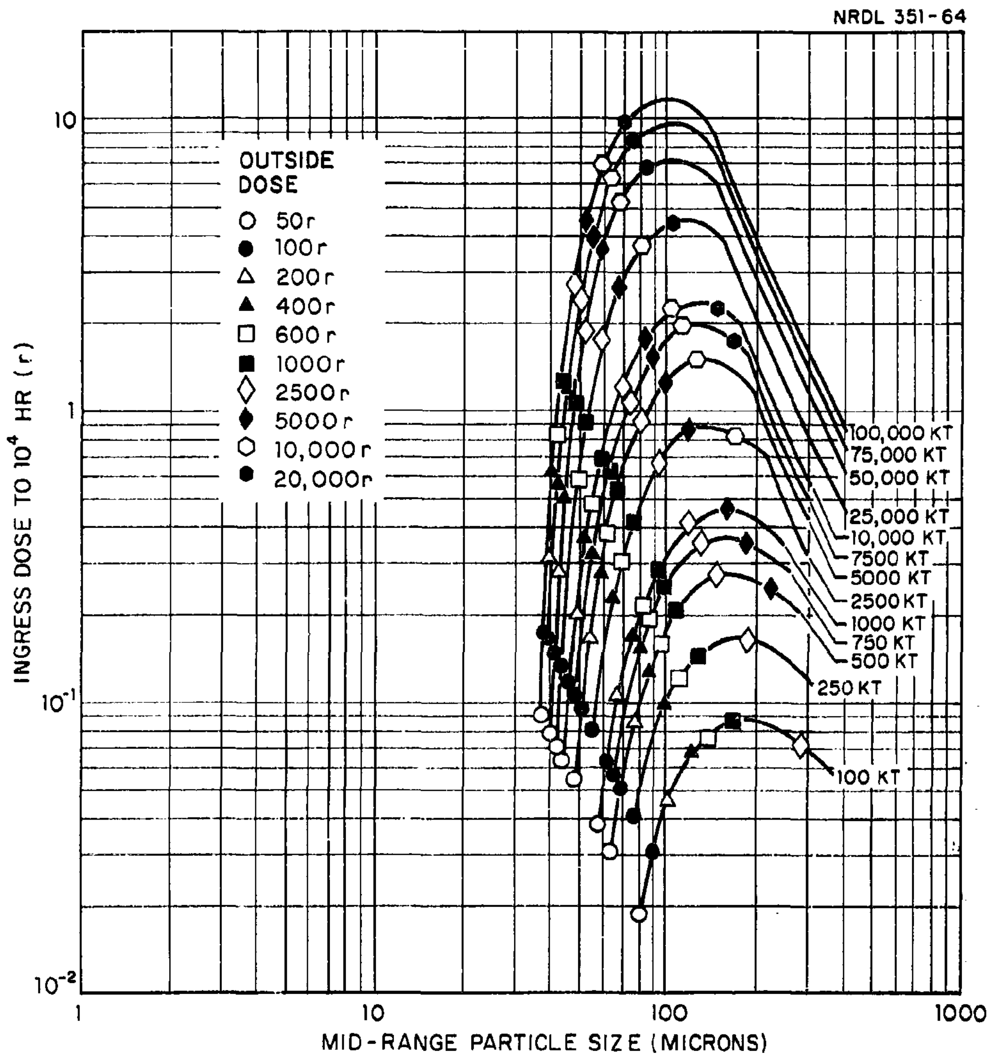

Fig. 3.6 Ingress Dose vs. Particle Size

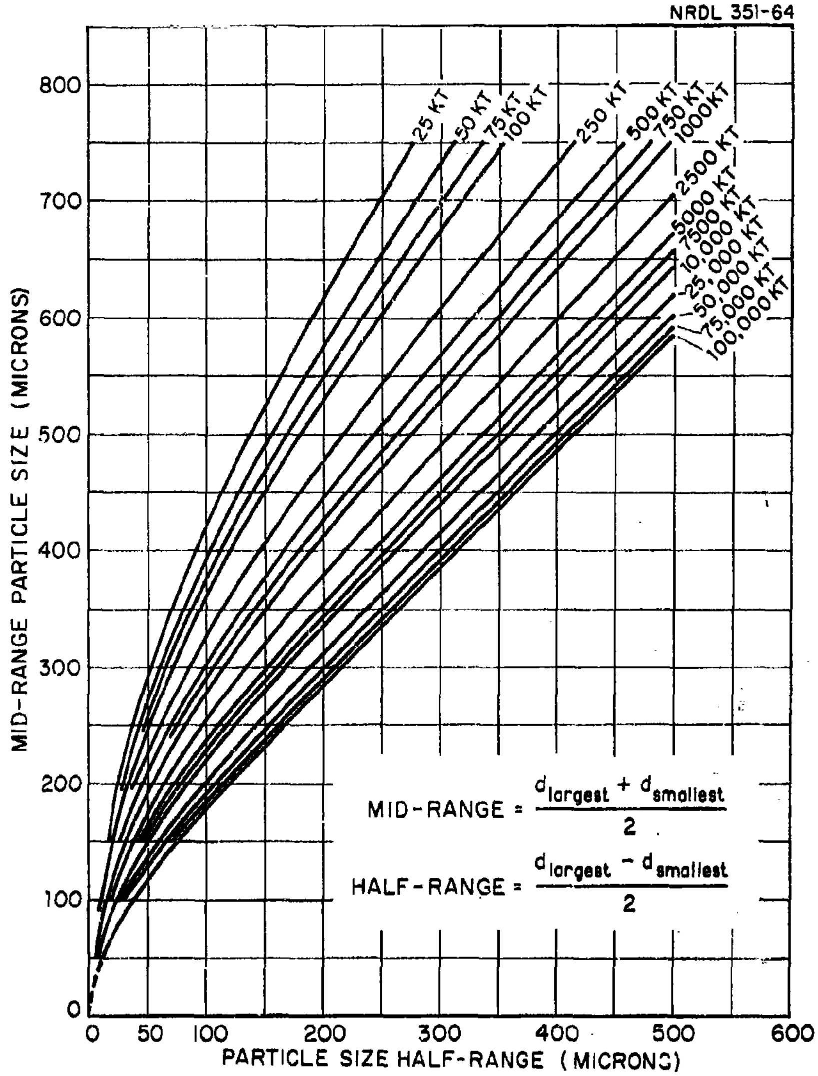

Fig. 3.7 Particle Size Mid-Range vs. Particle Size Half Range. Curves used to determine weapon yield producing fallout with physical properties defined by mid-range and half-range particle sizes (from Reference 6, Fig. 2B).

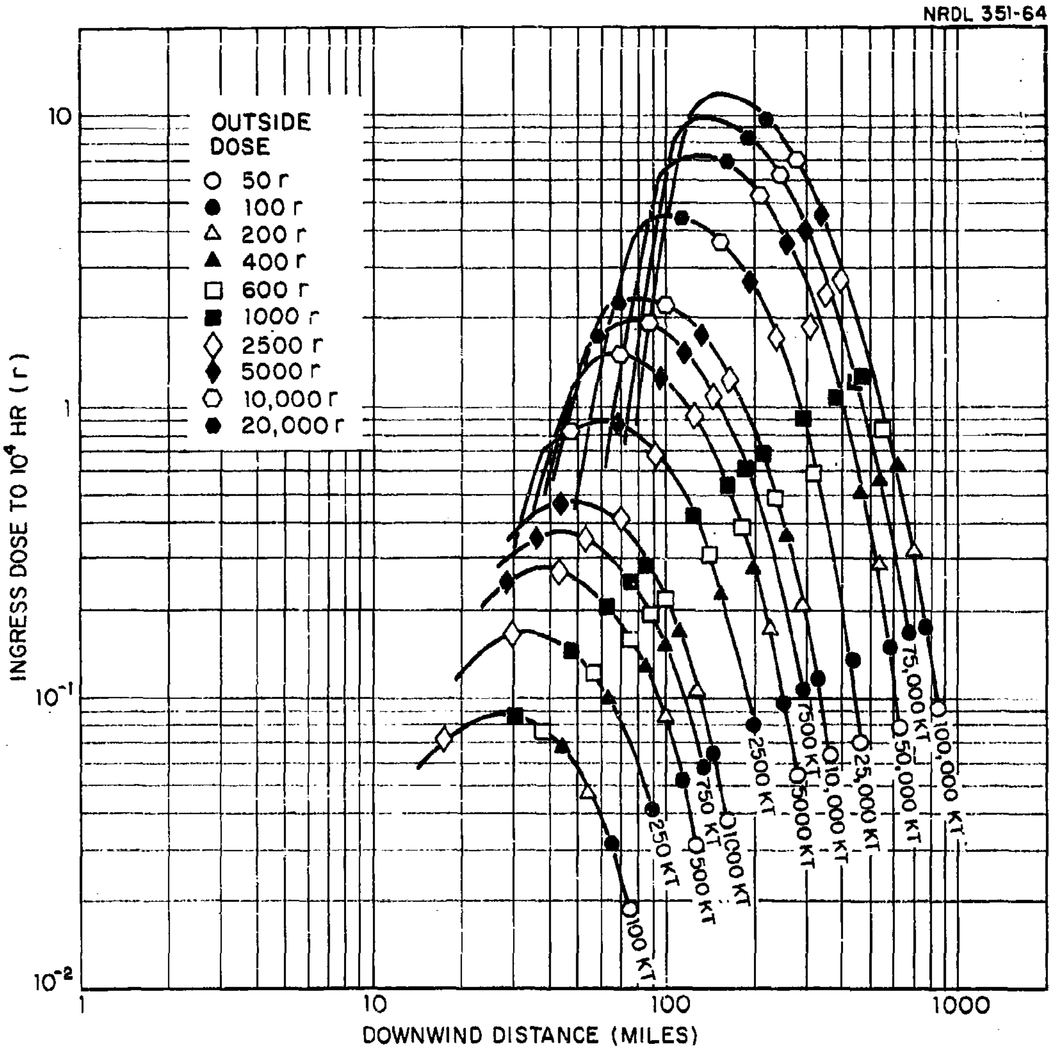

Fig. 3.8 Ingress Dose vs. Downwind Distance

3.6 TOTAL DOSE INSIDE SHELTER

As mentioned previously the shelter total dose is composed of at least two principal components: the dose due to the ingress of activity and the dose due to gamma penetration from fallout deposited over the shelter. The latter may be calculated from the outside dose and a known or assumed shielding factor. Outside doses were calculated in the process of calculating the ingress dose and are presented in Fig. 3.9 as a function of downwind distance. These doses range from very low values (no estimates were made below 50 r) to 75,000 r maximum at 117 miles downwind for a yield of 100,000 KT. At this location and for a yield of 100,000 KT, if a shelter had a shielding factor of 10,000 the dose due to gamma penetration from outside would be 7.5 r. The ingress dose would be 9.0 r (Fig. 3.8) and the shelter total dose would be 16.5 r, which may be compared to an acceptable dose. Or given an acceptable dose and shielding factor, an acceptable ingress dose can be calculated and compared to the estimated ingress dose for the weapon yield and location assumed.

3.7 DISCUSSION

The experimental data, dose estimates, and estimating technique as developed in this report for the prototype shelter should be useful as a basis for evaluating future needs in the shelter ventilation ingress program.

It is beyond the scope of this report to determine an acceptable shelter dose and the proportions of its several components, of which the ingress dose is one. The dose estimates presented are for external whole-body dose and no consideration has been given to contact or ingestion doses. Inhalation dose has not been mentioned as the particle sizes predicted by the fallout model and used experimentally are too large for retention by the respiratory tract.

Data uncertainties and the assumptions and simplifications necessary to estimate ingress doses dictated the development of a "worst case". The "worst case" is based on total penetration as opposed to a more realistic case where only about 50 % would be carried into the living area. The penetration curve represents a best fit by eye to the data points. It is a poor fit for the largest particle size groups and does not represent maximum values throughout most of its range.

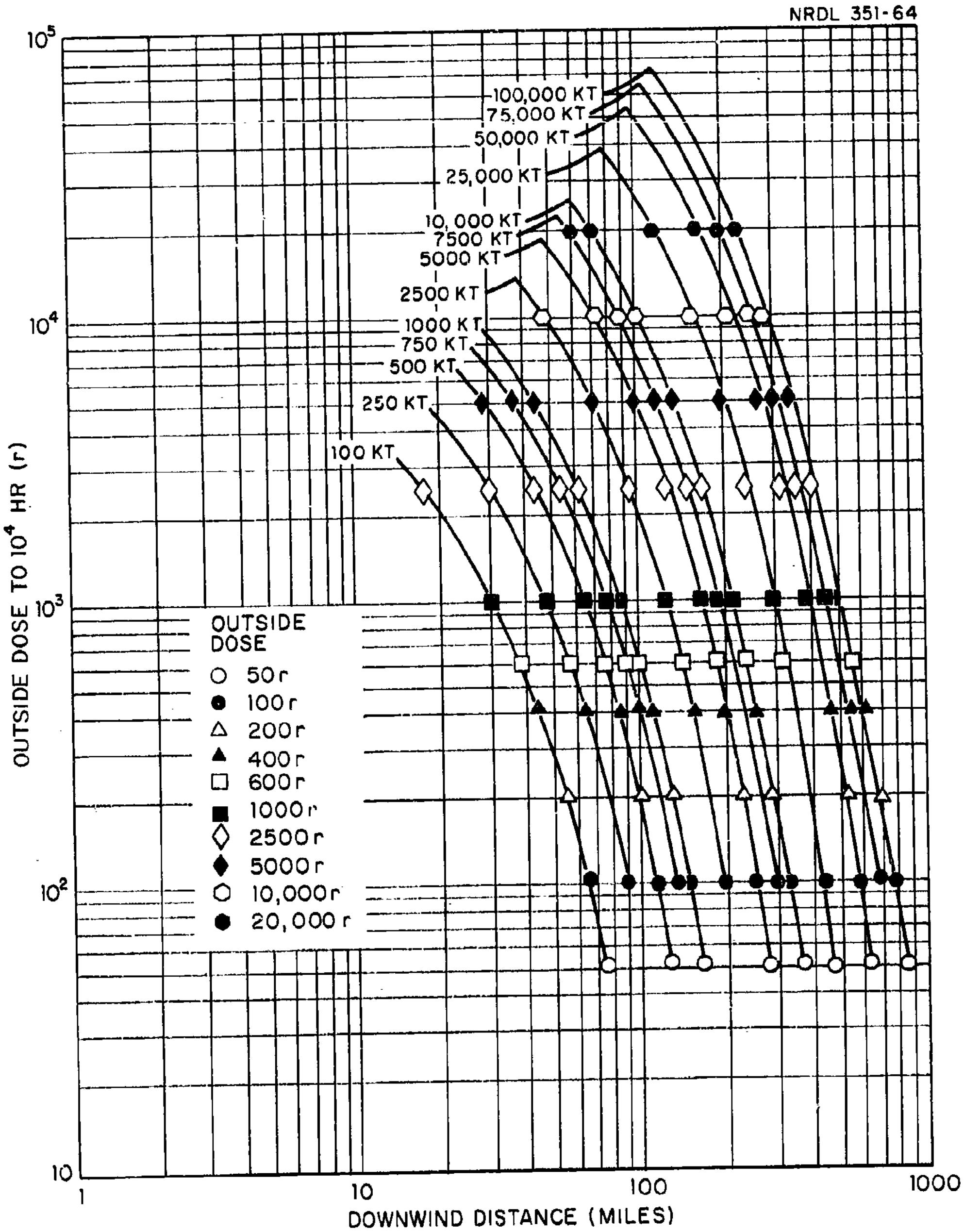

Fig. 3.9 Outside Dose vs. Downwind Distance

Uncertainty as to the amount of material dispersed increases from plus or minus 10 % for the smaller particle sizes to possibly as high as 30 % for the largest particle sizes. Other uncertainties with respect to sampling and counting have been previously discussed. It is estimated that use of the total penetration is more than adequate to provide a "worst" case for particle sizes up to 350 μ and should be adequate for the larger particle sizes where intake penetration is due primarily to bounce-in, in which case few, if any, particles will reach the shelter living space.

Note also that the maximum doses are due to large yield weapons which will have less than 100 % fission and doses would be reduced in direct proportion to the reduction in fission yield. However this factor provides some compensation for wind structures which might increase fallout deposition and dose at some locations.

It was assumed here (as indicated in section 3.4) that all material arrived at a single time. One refinement would be to estimate dose-rate build-up based on arrival rate as a function of time.

In summary, the greatest uncertainties in the dose estimates are associated with large mid-range particle sizes and their concomitant large ranges of particle sizes. It is expected, however, that refinements in data and dose estimating techniques will produce little change in the maximum ingress dose estimates for the conditions for which they were made.

In evaluating future needs the assumptions and limitations required to estimate the ingress dose may suggest the need for: additional experimental data for other surface wind conditions or for other shelter and ventilation designs; refinement in dose estimating techniques and extension to other wind structures, other fallout models, or multiple detonations.

REFERENCES

1. W. E. Strope. Operation PLUMBBOB, Evaluation of Countermeasure System Components and Operation Procedures. Civil Effects Test Group, AEC, WT-1464, August 14, 1958.

2. P. D. LaRiviere, et al. Small Boy Project 2.9 Report, Fallout Collection and Gross Sample Analysis (U). U. S. Naval Radiological Defense Laboratory, POIR 2215 (September 1962)(Secret-Restricted Data).

3. W. E. Strope, et al. Specifications and Cost of a Standardized Series of Fallout Shelters. U. S. Naval Radiological Defense Laboratory, USNRDL-TR-366 (October 6, 1959).

4. W. L. Owen, J. D. Sartor. Radiological Recovery of Land Target Components Complex I and Complex II. U. S. Naval Radiological Defense Laboratory, USNRDL-TR-570 (May 25, 1962).

5. W. S. Kehrer. A Disperser for Depositing Simulated Dry Fallout Material on Large Roof Surfaces. U. S. Naval Radiological Defense Laboratory, USNRDL-TR-609 (December 16, 1962).

6. D. E. Clark, Jr., W. C. Cobbin. Some Relationships Among Particle Size, Mass Level and Radiation Intensity of Fallout from a Land Surface Nuclear Detonation. U. S. Naval Radiological Defense Laboratory, USNRDL-TR-639 (March 21, 1963).

7. H. R. Rinnert. Estimates of Radiation Geometry and Energy Responses for the USNRDL "Model 1954-56" Gamma-Intensity Time Recorder (GITR). U. S. Naval Radiological Defense Laboratory, USNRDL-TR-719 (January 1964).

8. L. G. Porteous. Design Modifications and 1962 Cost Analyses for a Standardized Series of Fallout Shelters. U. S. Naval Radiological Defense Laboratory, USNRDL-TR-582 (17 September 1962).

9. W. E. Strope. The USNRDL Shelter Program. U. S. Naval Radiological Defense Laboratory, USNRDL-R&L-119 (21 August 1961).

APPENDIX A

METHOD OF ESTIMATING INGRESS DOSE

Fallout doses were calculated by selecting a suitable standard intensity for a given yield and determining the corresponding mid-range particle size from Fig. 3 of Reference 6. From Fig. 4 of Reference 6, the downwind distance for this mid-range particle size was determined. The downwind distance divided by the wind speed (15 mph) gave an approximate mean time of fallout arrival for this location and yield, which was used to determine the dose rate multiplier (DRM) from an enlarged version of Fig. 2.2 of Reference 4. The DRM is the ratio of dose (from a given time to 10^4 hours) to the standard intensity, based on decay. The standard intensity multiplied by the DRM gave the dose for the specified conditions. This dose is referred to as the "outside dose" with reference to a shelter in this report.

To calculate the ingress dose let

r_o = standard intensity outside	r/hr at 1 hr
M = mass contour ratio	$g/ft^2/r_o$

Then the fallout mass per unit area is

$$r_o M \qquad g/ft^2$$

and the total mass penetrating the shelter intakes is

$$r_o MK \qquad g$$

where K is the total penetration ratio in g penetration/g/ft^2 of fallout deposit for the particle size mid-range corresponding to r_o. Assuming that the total mass penetrating the intakes is deposited uniformly over the shelter living area floor, the penetrating mass per unit area in the shelter is then

$$r_o MK/1200 \qquad g/ft^2$$

for a shelter area of 1200 ft^2. Assuming that there has been no significant particle size shift which would change the mass contour ratio, the standard intensity in an extended field for the unit area deposit found for the shelter would be

$$r_o MK/1200M \text{ or } r_o K/1200 \qquad \text{r/hr at 1 hr.}$$

The ratio of the intensity 3 ft above the center of a 1200 ft^2 circular area to the intensity 3 ft above an infinite plane, both uniformly contaminated with the same mass (activity) per unit area, is 0.340. (The use of a circular area equal to the rectangular area of the shelter floor results in no significant difference in dose estimates for the size of area considered.)

This ratio was taken from Fig. A.1* which was based on equations given in Appendix A of Reference 7 for photon energies of 0.5, 1.0 and 2.0 Mev. In this range of energies there was no significant difference in the values obtained and the curve presented is for 1.0 Mev.

Let r_I = the standard intensity inside the shelter due to ingress deposit, then

$$\begin{aligned} r_I &= 0.340\, r_o\, K/1200 \qquad \text{r/hr at 1 hr} \\ &= 0.283 \times 10^{-3}\, K\, r_o \end{aligned}$$

Since we are primarily interested in dose and the same DRM applies inside and outside on the assumption of instantaneous intake and deposit, then dose may be substituted for intensity and

$$D_I = 0.283 \times 10^{-3}\, K\, D_o \qquad r \qquad (A.1)$$

and

$$D_I/D_o = 0.283 \times 10^{-3}\, K \qquad (A.2)$$

*Private communication from H. R. Rinnert of NRDL.

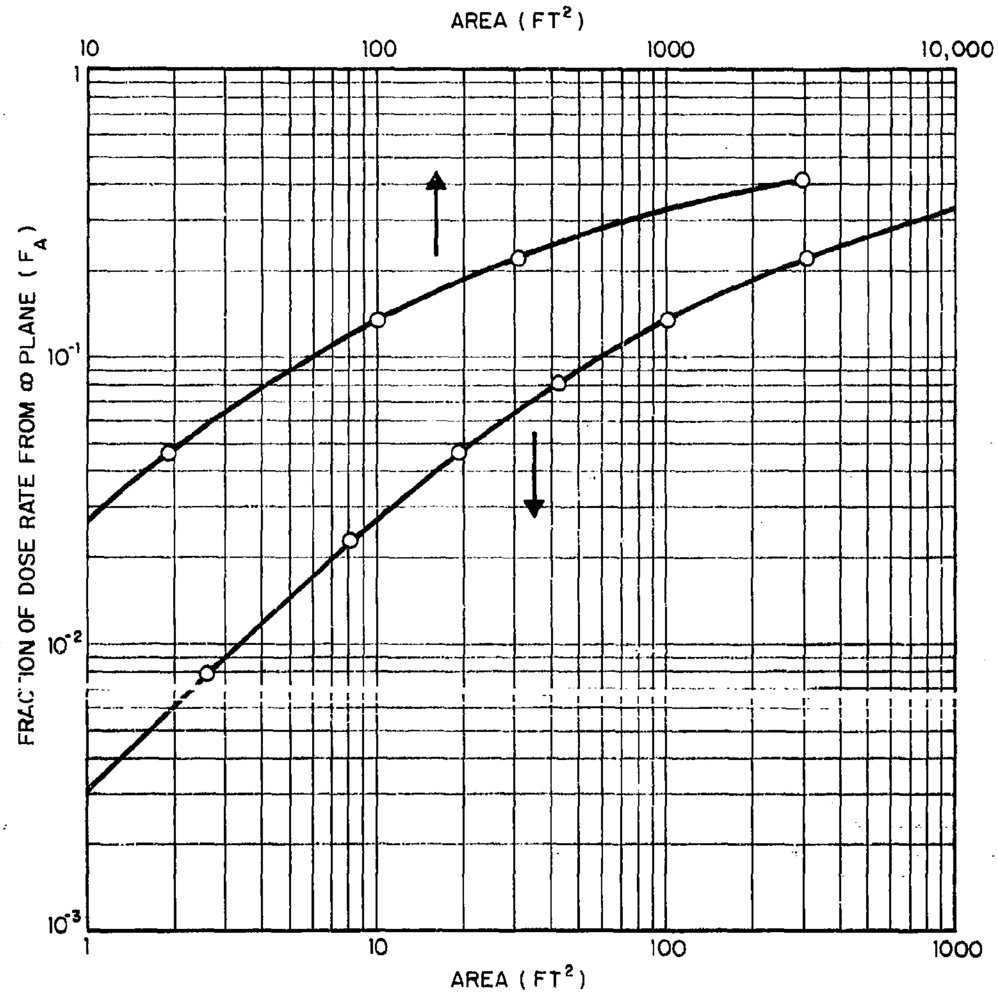

Fig. A.1 Fraction of Infinite Plane Dose Rate vs. Area

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NON-INGESTED DOSE ASSOCIATED WITH PARTICULATE INGRESS INTO A PROTOTYPE SHELTER VIA THE VENTILATION SYSTEM

by M. M. Bigger, R. J. Crew and R. K. Fuller

SPECIAL SUMMARY (Pages A-D, inclusive; for OCD use as detached document)

PROBLEM

Fallout carried into a shelter via the shelter ventilation system becomes one of several sources of shelter radiation dose. Estimates of these doses are required to assess the hazard and thus determine requirements for ventilation countermeasures. Countermeasure specifications must then be developed to meet these requirements.

Particle transport into a shelter via a ventilation system is a function of particle physical characteristics-size, specific gravity, and shape; and ventilation system characteristics-air volume rate, air velocities, and air path. The resulting dose is a function of time of exposure, the mass and disposition of the particles in the shelter, and fallout radiological characteristics such as specific activity and decay.

Relationships between particle characteristics and ventilation system characteristics are needed to estimate ingress doses for various fallout situations, defined in terms of particle characteristics and shelter ventilation characteristics. Estimated ingress doses can then be compared to an acceptable ingress dose to determine if ventilation countermeasures are needed; and if needed to provide a basis for countermeasure specifications.

BACKGROUND

Shelter ingress tests were first conducted at Operation PLUMBBOB on a buried shelter which was ventilated at a rate of 600 cfm. Air was drawn from a low velocity ramp-type entrance tunnel through two mushroom type intakes at the sides of the shelter door. From the results after two shots it was estimated that no inhalation hazard would have existed in the shelter and that the external dose due to ingress activity would have been on the order of the dose due to gamma penetration from fallout deposited over the shelter. It was concluded that no filter would have been necessary but that the results were not generalized enough to extrapolate to other fallout conditions.

In 1959 a prototype 100-man underground shelter of the type used at Operation PLUMBBOB was constructed at Camp Parks, California. A 1500 cfm ventilation system using "absolute" filters was installed. The ventilation fan and filters were located at the shelter door, in a landing area at the foot of an enclosed stairway. Air entered through mushroom type intakes, one on each side of the ground level door. The tests reported herein were conducted on this shelter and ventilation system.

At the conclusion of the prototype 100-man shelter ventilation ingress tests preparations were made for ingress testing at Shot Small Boy under actual fallout conditions. These tests were designed to determine particulate penetration of simple hooded intakes as a cross function of particle size and intake face velocity at flow rates suitable for a family type shelter. No such cross function could be derived from the data; the principal results were that the activity collected by the hooded intakes at three downwind locations was 25 percent or less of the activity collected by an open (unhooded) intake at the same location. Fifty percent or more of each hooded intake activity was associated with particles smaller than 44 microns in diameter and negligible amounts were associated with particles larger than 150 or 300 microns.

OBJECTIVES

(a) To determine particulate penetration into and distribution in the USNRDL experimental shelter as a function of particle size due to operation of the ventilation system without filters.

(b) To estimate the dose in the shelter living area as a function of particle size due to particulate deposition.

SCOPE

This report includes the experimental results obtained from the prototype shelter ventilation ingress tests and a curve derived therefrom of particulate penetration as a function of particle size assuming that penetration is directly proportional to outside fallout deposit mass.

Shot Small Boy data was adjusted in the ratio of shelter to Shot Small Boy test flow rates and prototype shelter and Small Boy penetration curves compared. No adjustment for differences in face velocities was made as no proportionality is known.

Ingress doses were estimated for the prototype shelter based on the penetration curve derived from the test data and a fallout model which gives standard intensity as a function of particle size.

These ingress dose estimates are limited to the prototype shelter under the conditions for which experimental data were obtained and to predicted fallout conditions along the "hot line" at locations downwind from a single nuclear detonation of various yields of 100 percent fission weapons. A 15 mph wind at all altitudes is assumed in application of the fallout model.

APPROACH

Deposition of Several narrow size ranges of particles within the shelter and outside the shelter in the vicinity of the air intake fittings was determined experimentally for a zero wind condition. From these data a relation of total penetration to mass deposited per unit area outside was determined for each particle size range. A curve was drawn for these penetration factors as a function of particle size and compared to several curves derived from the appropriate data obtained at Shot Small Boy.

Ingress doses were calculated from penetration factors for a "worst case". For this purpose it was assumed that all of the fallout penetrating the ventilation intakes was deposited in the shelter living area, though there is evidence that as little as 50 percent may reach the living area, the remainder being deposited on the steps and landing of the entrance. To provide a means of determining particle sizes of importance to the shelter ventilation ingress problem the ingress dose estimates are presented graphically as a function of mid-range particle size (if d_1 and d_2 = largest and smallest particle size respectively, then $d_1 + d_2/2$ = midrange particle size). For any given lower limit of significant ingress dose the corresponding mid-range particle sizes can be determined from these curves. Fallout model mid-range particle sizes are presented as a function of particle size half-range (defined as $(d_1-d_2)/2$) so that for the mid-range particle sizes determined as described above, the full range of particle sizes of significance to the ingress problem can be determined.

FINDINGS

The experimental results indicated that particle penetration by the largest size range (500-700 microns) appeared to be due principally to bounce-in rather than entrainment by the air stream. Otherwise penetration of intakes is an inverse function of particle size and a straight line was the best fit to a log-log plot of the data. Relatively good agreement was found with the small amount of applicable Shot Small Boy data.

The maximum estimated ingress dose was 11.8 r at 167 miles downwind from a 100,000 KT detonation (if 100 % fission was assumed). For a given acceptable ingress dose or the lower limit of significant ingress dose the curves presented can be used to determine the particle sizes of importance.

CONCLUSION

If ingress dose estimates are needed for ventilation or fallout conditions other than those considered then this report may be useful as a basis for planning and improving experimental and estimating techniques.

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